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Gravitation at Very Short Distances

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Abstract

In this note, it is discussed why attempts to renormalize conventional quantum gravity may be based on a false presumption, because, according to Verlinde's entropic view of gravity, the gravitational force between two elementary particles vanishes.

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Gauge theories such as quantum electrodynamics [1], constructed by Dyson, Feynman, Schwinger and Tomonaga, quantum chromodynamics [2], due to Fritzsche, Gell-Mann, Gross, Nambu and Wilczek, and the standard model [3], originated by Glashow, 't Hooft, Salam, Veltman and Weinberg, are renormalizable. This despite the divergences which occur because of employing singular products of fields at the same spacetime point.

When the same approach is applied to gravity, one finds non-renormalizability, because the gravitational interaction is too large at very short distances. This is the principal reason why string theory is favored in which the uncontrollable divergences are ameliorated by replacing local fields by extended objects whose interactions are suitably spread out in spacetime and can thereby avoid the previous divergences and lead to a finite theory.

In this note we suggest that the non-renormalizability of the non-string approach may be based on a false presumption.

In the quantum electrodynamics of photons and electrons, there exists a primordial vertex of the photon to the electron with coupling e , the electronic charge, and the whole renormalizable theory is built up upon this. Similarly for quantum chromodynamics there is a primordial gluon-quark vertex.

The presumption in quantum gravity is generically that there exists a corresponding primordial graviton-electron vertex (for example) with a non-zero coupling related to Newton's constant. The non-renormalizability can then be ascribed to the fact that this coupling becomes too large at very short distances, when compared to the corresponding coupling in a renormalizable theory.

If we consider two electrons, at a very short distance apart, conventional wisdom is that the gravitational force is more than forty orders of magnitude smaller than the electromagnetic force.

If we adopt an entropic view [4] (for one application, see [5]), the situation is changed.

According to the entropic view, the force of gravity, Newton's law, is explicable always as an entropy increase. In this case, the gravitational force between two isolated electrons whose entropy cannot increase, is not merely extremely small compared to the electromagnetic force, it is zero!!

At least one of the two objects must have sufficiently many subcomponents that its entropy is meaningful. It is known that neutrons are attracted to the Earth which contains $\sim 10^{51}$ nucleons. The question is then how many constituents, N , are necessary. Probably it must satisfy $N \gg \sqrt{N}$ in order that fluctuations are sufficiently small, so that *e.g.* $N \geq 100$.

While it is known that neutrons are attracted to the Earth, from experiment, when both bodies are elementary, like electrons, we expect zero gravitational force.

This then implies that the primordial electron-graviton vertex is not exceptionally large at very short distances, but actually vanishes.

Therefore there is no reason to expect gravity to be renormalizable, or to employ string theory. In the entropic approach, if there were a graviton it would be a collective excitation more like a phonon than a photon, and not an elementary particle. Because the gravitational force between two elementary particles is zero, there is no reason for conventional quantum gravity to be renormalizable.

It is known from the beautiful experiment of Colella, Overhauser and Werner [6] that a single neutron is attracted to the earth. On the other hand, with only two elementary particles, like two electrons (or two neutrons) with fixed positions (and spins) we expect a zero force in the entropic scenario. In principle, the experiment of Colella et al [6] could be replicated with a small sample of matter (say 1000 particles) as the source of the gravitational field for a split neutron beam. One could then observe that as the number of particles diminishes in the source the fluctuations would destroy the gravitational potential. Of course in practice such an experiment would be impossibly hard to achieve.

It is known that Newton's law is valid [7] down to a distance of a few tens of microns, or $\sim 10^{-5}$ m, while we would expect it to break down in matter of normal density before reaching an atomic scale, $\sim 10^{-10}$ m. If we require one thousand (one million) surrounding atoms it would suggest $\sim 10^{-9}$ m ($\sim 10^{-8}$ m) as the shortest scale at which Newton's law could become approximately valid. We therefore can reasonably expect a deviation from the inverse-square law of Newton to be experimentally detectable in principle, although almost impracticably challenging [7] in practice, at such length scales.

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